

AMENDMENTS TO THE CLAIMS

- Claim 1. (Original) A method for producing single-wall carbon nanotubes, comprising:
- (a) providing a supported catalyst of catalytic metal comprising iron (Fe) and molybdenum (Mo) on magnesium oxide (MgO) particles, wherein the catalyst has been prepared by combusting iron, molybdenum and magnesium oxide precursors to form the supported catalyst; and
 - (b) contacting the catalyst with a gaseous stream comprising a carbon-containing feedstock at a sufficient temperature and for a contact time sufficient to make a carbon product comprising single-wall carbon nanotubes.
- Claim 2. (Original) The method of claim 1 wherein iron and molybdenum are present in a weight ratio range from about 10 to 1 to about 2 to 1.
- Claim 3. (Original) The method of claim 1 wherein the iron and molybdenum are present in a molar ratio range from about 20 to 1 to about 3 to 1.
- Claim 4. (Original) The method of claim 1 wherein the catalytic metal is present on the magnesium oxide particles on a weight basis from about 0.5 wt% to at most about 10 wt% of the weight of the magnesium oxide particles.
- Claim 5. (Original) The method of claim 1 wherein the iron precursor is selected from the group consisting of iron (III) nitrate, iron sulfite, iron sulfate, iron carbonate, iron acetate, iron citrate, iron gluconate, iron hexacyanoferrite, iron oxalate, tris(ethylenediamine) iron sulfate and combinations thereof.
- Claim 6. (Original) The method of claim 1 wherein the iron precursor comprises iron (III) nitrate.
- Claim 7. (Original) The method of claim 1 wherein the molybdenum precursor comprises ammonium heptamolybdate.
- Claim 8. (Original) The method of claim 1 wherein the magnesium oxide precursor comprises magnesium nitrate.

Claim 9. (Original) The method of claim 1 wherein the combusting includes a foaming agent.

Claim 10. (Original) The method of claim 1 wherein the combusting includes at least one compound selected from the group consisting of a citric acid, urea, glycine, hydrazine, sucrose, carbohydrazide, oxalyl dihydrazide, sugars, alcohols, and combinations thereof.

Claim 11. (Original) The method of claim 1 wherein the combusting includes citric acid.

Claim 12. (Original) The method of claim 1 wherein the combusting is conducted by exposing the precursors to temperatures in the range of about 150°C and about 1200°C.

Claim 13. (Original) The method of claim 1 wherein the combusting is conducted by exposing the precursors to temperatures in the range of about 200°C and about 700°C.

Claim 14. (Original) The method of claim 1 wherein the combusting is conducted by exposing the precursors to temperatures in the range of about 250°C and about 650°C.

Claim 15. (Original) The method of claim 1 wherein the precursors are sprayed to form an aerosol prior to combustion.

Claim 16. (Original) The method of claim 1 wherein the combusting comprises contacting the precursors with a heated surface.

Claim 17. (Original) The method of claim 1 wherein the catalyst is exposed to a sulfur-containing compound.

Claim 18. (Original) The method of claim 17 wherein the sulfur-containing compound is selected from the group consisting of thiophene, hydrogen sulfide, a mercaptan and combinations thereof.

Claim 19. (Original) The method of claim 17 wherein the sulfur-containing compound comprises thiophene.

Claim 20. (Original) The method of claim 1 wherein the catalyst has a cross-sectional dimension of less than about 100 microns.

Claim 21. (Original) The method of claim 1 wherein the catalyst has a cross-sectional dimension of less than about 30 microns.

Claim 22. (Original) The method of claim 1 wherein the catalyst has a bulk density less than about 0.3 g/cm^3 .

Claim 23. (Original) The method of claim 1 wherein the catalyst has a bulk density less than about 0.1 g/cm^3 .

Claim 24. (Original) The method of claim 1 further comprising reducing the metal prior to the contacting step.

Claim 25. (Original) The method of claim 24 wherein the reducing is done with a reducing gas.

Claim 26. (Original) The method of claim 25 wherein the reducing gas comprises hydrogen.

Claim 27. (Original) The method of claim 1 wherein the metal is reduced during the contacting step.

Claim 28. (Original) The method of claim 1 wherein the temperature is in a range of about 500°C and about 1500°C .

Claim 29. (Original) The method of claim 1 wherein the temperature is in the range of about 650°C and about 950°C .

Claim 30. (Original) The method of claim 1 wherein the temperature is in the range of about 800°C and about 950°C .

Claim 31. (Original) The method of claim 1 wherein the carbon-containing feedstock comprises a compound selected from the group consisting of methane, hydrocarbons, carbon monoxide and combinations thereof.

Claim 32. (Original) The method of claim 1 wherein the gaseous stream comprising the carbon-containing feedstock comprises methane.

Claim 33. (Currently amended) The method of claim 1 further comprising mixing hydrogen with the ~~gaseous~~ gaseous stream comprising carbon-containing feedstock.

Claim 34. (Original) The method of claim 1 wherein the gaseous stream comprising the carbon-containing feedstock also comprises hydrogen.

Claim 35. (Original) The method of claim 1 wherein the gaseous stream comprising the carbon-containing feedstock comprises a mixture of methane and hydrogen.

Claim 36. (Original) The method of claim 1 wherein the contact time is in a range of about 0.1 seconds and about 60 minutes.

Claim 37. (Original) The method of claim 1 wherein the contact time is in a range of about 0.1 seconds and about 30 minutes.

Claim 38. (Original) The method of claim 1 wherein the contact time is in a range of about 10 seconds and about 10 minutes.

Claim 39. (Original) The method of claim 1 wherein the single-wall carbon nanotubes have diameters controlled by the contact time in the contacting step.

Claim 40. (Original) The method of claim 1 wherein the single-wall carbon nanotubes have lengths controlled by the contact time in the contacting step.

Claim 41. (Original) The method of claim 1 wherein the contacting is done at a pressure between about 0.1 atmospheres and about 200 atmospheres.

Claim 42. (Original) The method of claim 1 further comprising removing the catalyst from the carbon product with an acid.

Claim 43. (Original) The method of claim 42 wherein the acid is selected from the group consisting of citric acid, acetic acid, nitric acid, sulfuric acid, hydrochloric acid, hydrofluoric acid and combinations thereof.

Claim 44. (Original) The method of claim 42 wherein the acid comprises hydrochloric acid.

Claim 45. (Original) The method of claim 1 wherein at least about 50 wt% of carbon in the carbon product is single-wall carbon nanotubes.

Claim 46. (Original) The method of claim 1 wherein at least about 80 wt% of carbon in the product is single-wall carbon nanotubes.

Claim 47. (Original) The method of claim 1 wherein at least about 90 wt% of carbon in the product is single-wall carbon nanotubes.

Claim 48. (Original) The method of claim 1 wherein at least about 95 wt% of carbon in the product is single-wall carbon nanotubes.

Claim 49. (Original) The method of claim 1 wherein the catalyst is flowed through a transport reactor entrained in the gaseous stream comprising the carbon-containing feedstock.

Claim 50. (Original) The method of claim 49 wherein at least one other gaseous stream comprising the carbon-containing feedstock is introduced to the reactor at more than one inlet.

Claim 51. (Original) The method of claim 50 wherein the at least one other gaseous stream comprises hydrogen.

Claim 52. (Original) The method of claim 49 wherein the reactor comprises more than one zone wherein each zone is capable of maintaining a different set of reaction conditions.

Claim 53. (Original) The method of claim 49 wherein the reactor further comprises a solid-gas separator selected from the group consisting of a wet scrubber, a cyclone, an electrostatic precipitator, filter, and combinations thereof.

Claim 54. (Original) The method of claim 49 wherein a dispersing aid is used in the transport reactor.

Claim 55. (Original) The method of claim 54 wherein the dispersing aid is a material selected from the group consisting of metal oxide particles, sand, quartz beads, ceramic particles, refractory material and combinations thereof.

Claim 56. (Original) The method of claim 1 wherein the catalyst is fluidized by the gaseous stream comprising the carbon-containing feedstock in a fluidized bed reactor.

Claim 57. (Original) The method of claim 56 wherein the fluidized bed reactor comprises more than one zone wherein each zone is capable of maintaining a different set of reaction conditions.

Claim 58. (Original) The method of claim 56 wherein a fluidizing aid is fluidized in the fluidized bed reactor.

Claim 59. (Original) The method of claim 58 wherein the catalyst and the carbon product are separated from the fluidizing aid by differential elutriation.

Claim 60. (Original) The method of claim 58 wherein the fluidizing aid exchanges heat with the catalyst.

Claim 61. (Original) The method of claim 58 wherein the fluidizing aid acts as a reactor wall scrubber.

Claim 62. (Original) The method of claim 58 wherein the fluidizing aid is a material selected from the group consisting of metal oxide particles, sand, quartz beads, ceramic particles, refractory material and combinations thereof.

Claim 63. (Original) The method of claim 1 wherein the contacting occurs in a moving bed reactor, wherein the reactor has a moving bed comprising the catalyst and essentially-inert particles.

Claim 64. (Original) The method of claim 63 wherein the moving bed reactor comprises more than one zone wherein each zone is capable of maintaining a different set of reaction conditions.

Claim 65. (Original) The method of claim 63 wherein the gaseous stream comprising the carbon-containing feedstock is introduced into the reactor at more than one inlet.

Claim 66. (Original) The method of claim 63 wherein the essentially-inert particles comprise a material selected from the group consisting of metal oxide particles, sand, quartz beads, ceramic particles, refractory material and combinations thereof.

Claim 67. (Original) The method of claim 63 wherein the essentially-inert particles are removed from the reactor, circulated and re-introduced to the reactor.

Claim 68. (Original) The method of claim 63 where the essentially-inert particles are regenerated after exiting the reactor.

Claim 69. (Original) The method of claim 63 wherein the essentially-inert particles are heated after exiting the reactor to produce essentially-inert heated particles.

Claim 70. (Original) The method of claim 68 wherein the essentially-inert heated particles are introduced into the reactor and exchange heat with the catalyst.

Claim 71. (Original) The method of claim 63 further comprising separating the catalyst and the carbon product from the essentially-inert particles.

Claim 72. (Original) The method of claim 71 wherein the separating is done by differential elutriation.

Claim 73. (Original) The method of claim 71 wherein the separating comprises a component selected from the group consisting of a cyclone, a classifier, a solid-gas separator, a disengaging section, a wet scrubber, a cyclone, an electrostatic precipitator, a filter and combinations thereof.

Claim 74. (Original) The method of claim 63 wherein the moving bed reactor is a counter-current moving bed reactor, wherein the counter-current moving bed reactor has a moving bed comprising the essentially-inert particles that move in a direction counter-current to flows of the catalyst and the gaseous stream comprising the carbon-containing feedstock.

Claim 75. (Original) The method of claim 63 wherein the moving bed reactor is a concurrent-flow moving bed reactor wherein the essentially-inert particles and the catalyst flow in the same direction.

Claim 76. (Original) The method of claim 75 wherein the gaseous stream comprising the carbon-containing feedstock, the essentially inert particles and the catalyst flow in the same direction.

Claim 77. (Original) The method of claim 75 wherein the gaseous stream comprising the carbon-containing feedstock flows in an opposite direction to movement of the essentially-inert particles and the catalyst.

Claim 78. (Original) A method for producing single-wall carbon nanotubes, comprising:

- (a) providing a catalyst of catalytic metal comprising at least one metal from the group consisting of Group VIB and Group VIIIB and a support selected from the group consisting of alumina, magnesia, silica, zirconia and combinations thereof;
- (b) sulfiding the catalyst; and
- (c) contacting the catalyst with a gaseous stream comprising a carbon-containing feedstock at a sufficient temperature and for a contact time sufficient to make a carbon product comprising single-wall carbon nanotubes.

Claim 79. (Original) The method of claim 78 wherein the catalytic metal comprise Co and Mo.

Claim 80. (Original) The method of claim 78 wherein the support is magnesia.

Claim 81. (Original) The method of claim 78 wherein the catalyst is prepared by combusting precursors of the catalytic metal and the support.

Claim 82. (Original) The method of claim 81 wherein the precursors are combined with a foaming agent selected from the group consisting of citric acid, urea, glycine, hydrazine, sucrose, carbohydrazide, oxalyl dihydrazide, sugars, alcohols, and combinations thereof.

Claim 83. (Original) The method of claim 82 wherein the foaming agent comprises citric acid.

Claim 84. (Original) The method of claim 81 wherein the combusting is conducted by exposing the precursors to temperatures in the range of about 150°C and about 1200°C.

Claim 85. (Original) The method of claim 81 wherein the combusting is conducted by exposing the precursors to temperatures in the range of about 200°C and about 700°C.

Claim 86. (Original) The method of claim 81 wherein the combusting is conducted by exposing the precursors to temperatures in the range of about 250°C and about 650°C.

Claim 87. (Original) The method of claim 81 wherein the precursors are sprayed to form an aerosol prior to combustion.

Claim 88. (Original) The method of claim 81 wherein the combusting comprises contacting the precursors with a heated surface.

Claim 89. (Original) The method of claim 78 wherein the sulfiding is done by exposing the catalyst to a sulfur-containing compound selected from the group consisting of thiophene, hydrogen sulfide, a mercaptan and combinations thereof.

Claim 90. (Original) The method of claim 78 wherein the sulfiding is done prior to the contacting step.

Claim 91. (Original) The method of claim 78 wherein the sulfiding is done with the contacting step.

Claim 92. (Original) The method of claim 78 wherein the catalyst has a cross-sectional dimension of less than about 100 microns.

Claim 93. (Original) The method of claim 78 wherein the catalyst has a cross-sectional dimension of less than about 30 microns.

Claim 94. (Original) The method of claim 78 wherein the catalyst has a bulk density less than about 0.3 g/cm³.

Claim 95. (Original) The method of claim 78 wherein the catalyst has a bulk density less than about 0.1 g/cm³.

Claim 96. (Original) The method of claim 78 further comprising reducing the metal prior to the contacting step.

Claim 97. (Original) The method of claim 96 wherein the reducing is done with a reducing gas.

Claim 98. (Original) The method of claim 97 wherein the reducing gas comprises hydrogen.

Claim 99. (Original) The method of claim 78 wherein the metal is reduced during the contacting step.

Claim 100. (Original) The method of claim 78 wherein the temperature is in a range of about 500°C and about 1500°C.

Claim 101. (Original) The method of claim 78 wherein the temperature is in the range of about 650°C and about 950°C.

Claim 102. (Original) The method of claim 78 wherein the temperature is in the range of about 800°C and about 950°C.

Claim 103. (Original) The method of claim 78 wherein the carbon-containing feedstock comprises a compound selected from the group consisting of methane, hydrocarbons, carbon monoxide and combinations thereof.

Claim 104. (Original) The method of claim 78 wherein the gaseous stream comprising the carbon-containing feedstock comprises methane.

Claim 105. (Currently amended) The method of claim 78 further comprising mixing hydrogen with the ~~gaseous~~ gaseous stream comprising carbon-containing feedstock.

Claim 106. (Original) The method of claim 78 wherein the gaseous stream comprising the carbon-containing feedstock also comprises hydrogen.

Claim 107. (Original) The method of claim 78 wherein the gaseous stream comprising the carbon-containing feedstock comprises a mixture of methane and hydrogen.

Claim 108. (Original) The method of claim 78 wherein the contact time is in a range of about 0.1 seconds and about 60 minutes.

Claim 109. (Original) The method of claim 78 wherein the contact time is in a range of about 0.1 seconds and about 30 minutes.

Claim 110. (Original) The method of claim 78 wherein the contact time is in a range of about 10 seconds and about 10 minutes.

Claim 111. (Original) The method of claim 78 wherein the single-wall carbon nanotubes have diameters controlled by the contact time in the contacting step.

Claim 112. (Original) The method of claim 78 wherein the single-wall carbon nanotubes have lengths controlled by the contact time in the contacting step.

Claim 113. (Original) The method of claim 78 wherein the contacting is done at a pressure between about 0.1 atmospheres and about 200 atmospheres.

Claim 114. (Original) The method of claim 78 further comprising removing the catalyst from the carbon product with an acid.

Claim 115. (Original) The method of claim 114 wherein the acid is selected from the group consisting of citric acid, acetic acid, nitric acid, sulfuric acid, hydrochloric acid, hydrofluoric acid and combinations thereof.

Claim 116. (Original) The method of claim 114 wherein the acid comprises hydrochloric acid.

Claim 117. (Original) The method of claim 78 wherein at least about 50 wt% of carbon in the carbon product is single-wall carbon nanotubes.

Claim 118. (Original) The method of claim 78 wherein at least about 80 wt% of carbon in the product is single-wall carbon nanotubes.

Claim 119. (Original) The method of claim 78 wherein at least about 90 wt% of carbon in the product is single-wall carbon nanotubes.

Claim 120. (Original) The method of claim 78 wherein at least about 95 wt% of carbon in the product is single-wall carbon nanotubes.

Claim 121. (Original) The method of claim 78 wherein the catalyst is flowed through a transport reactor entrained in the gaseous stream comprising the carbon-containing feedstock.

Claim 122. (Original) The method of claim 121 wherein at least one other gaseous stream comprising the carbon-containing feedstock is introduced to the reactor at more than one inlet.

Claim 123. (Original) The method of claim 122 wherein the at least one other gaseous stream comprises hydrogen.

Claim 124. (Original) The method of claim 121 wherein the reactor comprises more than one zone wherein each zone is capable of maintaining a different set of reaction conditions.

Claim 125. (Original) The method of claim 121 wherein the reactor further comprises a solid-gas separator selected from the group consisting of a wet scrubber, a cyclone, an electrostatic precipitator, filter, and combinations thereof.

Claim 126. (Original) The method of claim 121 wherein a dispersing aid is used in the transport reactor.

Claim 127. (Original) The method of claim 126 wherein the dispersing aid is a material selected from the group consisting of metal oxide particles, sand, quartz beads, ceramic particles, refractory material and combinations thereof.

Claim 128. (Original) The method of claim 78 wherein the catalyst is fluidized by the gaseous stream comprising the carbon-containing feedstock in a fluidized bed reactor.

Claim 129. (Original) The method of claim 128 wherein the fluidized bed reactor comprises more than one zone wherein each zone is capable of maintaining a different set of reaction conditions.

Claim 130. (Original) The method of claim 128 wherein a fluidizing aid is fluidized in the fluidized bed reactor.

Claim 131. (Original) The method of claim 130 wherein the catalyst and the carbon product are separated from the fluidizing aid by differential elutriation.

Claim 132. (Original) The method of claim 130 wherein the fluidizing aid exchanges heat with the catalyst.

Claim 133. (Original) The method of claim 130 wherein the fluidizing aid acts as a reactor wall scrubber.

Claim 134. (Original) The method of claim 130 wherein the fluidizing aid is a material selected from the group consisting of metal oxide particles, sand, quartz beads, ceramic particles, refractory material and combinations thereof.

Claim 135. (Original) The method of claim 78 wherein the contacting occurs in a moving bed reactor, wherein the reactor has a moving bed comprising the catalyst and essentially-inert particles.

Claim 136. (Original) The method of claim 135 wherein the moving bed reactor comprises more than one zone wherein each zone is capable of maintaining a different set of reaction conditions.

Claim 137. (Original) The method of claim 135 wherein the gaseous stream comprising the carbon-containing feedstock is introduced into the reactor at more than one inlet.

Claim 138. (Original) The method of claim 135 wherein the essentially-inert particles comprise a material selected from the group consisting of metal oxide particles, sand, quartz beads, ceramic particles, refractory material and combinations thereof.

Claim 139. (Original) The method of claim 135 wherein the essentially-inert particles are removed from the reactor, circulated and re-introduced to the reactor.

Claim 140. (Original) The method of claim 135 where the essentially-inert particles are regenerated after exiting the reactor.

Claim 141. (Original) The method of claim 135 wherein the essentially-inert particles are heated after exiting the reactor to produce essentially-inert heated particles.

Claim 142. (Original) The method of claim 135 wherein the essentially-inert heated particles are introduced into the reactor and exchange heat with the catalyst.

Claim 143. (Original) The method of claim 135 further comprising separating the catalyst and the carbon product from the essentially-inert particles.

Claim 144. (Original) The method of claim 143 wherein the separating is done by differential elutriation.

Claim 145. (Original) The method of claim 143 wherein the separating comprises a component selected from the group consisting of a cyclone, a classifier, a solid-gas separator, a disengaging section, a wet scrubber, a cyclone, an electrostatic precipitator, a filter and combinations thereof.

Claim 146. (Original) The method of claim 135 wherein the moving bed reactor is a counter-current moving bed reactor, wherein the counter-current moving bed reactor has a moving bed comprising the essentially-inert particles that move in a direction counter-current to flows of the catalyst and the gaseous stream comprising the carbon-containing feedstock.

Claim 147. (Original) The method of claim 135 wherein the moving bed reactor is a concurrent-flow moving bed reactor wherein the essentially-inert particles and the catalyst flow in the same direction.

Claim 148. (Original) The method of claim 147 wherein the gaseous stream comprising the carbon-containing feedstock, the essentially inert particles and the catalyst flow in the same direction.

Claim 149. (Original) The method of claim 148 wherein the gaseous stream comprising the carbon-containing feedstock flows in an opposite direction to movement of the essentially-inert particles and the catalyst.

Claim 150. (Original) A method for producing single-wall carbon nanotubes, comprising:
(a) providing a catalyst of catalytic metal comprising cobalt and molybdenum on magnesium oxide particles;

- (b) sulfiding the catalyst; and
- (c) contacting the catalyst with a gaseous stream comprising a carbon-containing feedstock at a sufficient temperature and for a contact time sufficient to make a carbon product comprising single-wall carbon nanotubes.

Claim 151. (Original) The method of claim 150 wherein the catalyst is prepared by combusting precursors of the catalytic metal and the magnesium oxide particles.

Claim 152. (Original) The method of claim 151 wherein the precursors are combined with a foaming agent selected from the group consisting of citric acid, urea, glycine, hydrazine, sucrose, carbohydrazide, oxalyl dihydrazide, sugars, alcohols, and combinations thereof.

Claim 153. (Original) The method of claim 152 wherein the foaming agent comprises citric acid.

Claim 154. (Original) The method of claim 151 wherein the combusting is conducted by exposing the precursors to temperatures in the range of about 150°C and about 1200°C.

Claim 155. (Original) The method of claim 151 wherein the combusting is conducted by exposing the precursors to temperatures in the range of about 200°C and about 700°C.

Claim 156. (Original) The method of claim 151 wherein the combusting is conducted by exposing the precursors to temperatures in the range of about 250°C and about 650°C.

Claim 157. (Original) The method of claim 151 wherein the precursors are sprayed to form an aerosol prior to combustion.

Claim 158. (Original) The method of claim 151 wherein the combusting comprises contacting the precursors with a heated surface.

Claim 159. (Original) The method of claim 150 wherein the sulfiding is done by exposing the catalyst to a sulfur-containing compound selected from the group consisting of thiophene, hydrogen sulfide, a mercaptan and combinations thereof.

Claim 160. (Original) The method of claim 150 wherein the sulfiding is done prior to the contacting step.

Claim 161. (Original) The method of claim 150 wherein the sulfiding is done with the contacting step.

Claim 162. (Original) The method of claim 150 wherein the catalyst has a cross-sectional dimension of less than about 100 microns.

Claim 163. (Original) The method of claim 150 wherein the catalyst has a cross-sectional dimension of less than about 30 microns.

Claim 164. (Original) The method of claim 150 wherein the catalyst has a bulk density less than about 0.3 g/cm³.

Claim 165. (Original) The method of claim 150 wherein the catalyst has a bulk density less than about 0.1 g/cm³.

Claim 166. (Original) The method of claim 150 further comprising reducing the metal prior to the contacting step.

Claim 167. (Original) The method of claim 166 wherein the reducing is done with a reducing gas.

Claim 168. (Original) The method of claim 167 wherein the reducing gas comprises hydrogen.

Claim 169. (Original) The method of claim 150 wherein the metal is reduced during the contacting step.

Claim 170. (Original) The method of claim 150 wherein the temperature is in a range of about 500°C and about 1500°C.

Claim 171. (Original) The method of claim 150 wherein the temperature is in the range of about 650°C and about 950°C.

Claim 172. (Original) The method of claim 150 wherein the temperature is in the range of about 800°C and about 950°C.

Claim 173. (Original) The method of claim 150 wherein the carbon-containing feedstock comprises a compound selected from the group consisting of methane, hydrocarbons, carbon monoxide and combinations thereof.

Claim 174. (Original) The method of claim 150 wherein the gaseous stream comprising the carbon-containing feedstock comprises methane.

Claim 175. (Currently amended) The method of claim 150 further comprising mixing hydrogen with the ~~gaseous~~ gaseous stream comprising carbon-containing feedstock.

Claim 176. (Original) The method of claim 150 wherein the gaseous stream comprising the carbon-containing feedstock also comprises hydrogen.

Claim 177. (Original) The method of claim 150 wherein the gaseous stream comprising the carbon-containing feedstock comprises a mixture of methane and hydrogen.

Claim 178. (Original) The method of claim 150 wherein the contact time is in a range of about 0.1 seconds and about 60 minutes.

Claim 179. (Original) The method of claim 150 wherein the contact time is in a range of about 0.1 seconds and about 30 minutes.

Claim 180. (Original) The method of claim 150 wherein the contact time is in a range of about 10 seconds and about 10 minutes.

Claim 181. (Original) The method of claim 150 wherein the single-wall carbon nanotubes have diameters controlled by the contact time in the contacting step.

Claim 182. (Original) The method of claim 150 wherein the single-wall carbon nanotubes have lengths controlled by the contact time in the contacting step.

Claim 183. (Original) The method of claim 150 wherein the contacting is done at a pressure between about 0.1 atmospheres and about 200 atmospheres.

Claim 184. (Original) The method of claim 150 further comprising removing the catalyst from the carbon product with an acid.

Claim 185. (Original) The method of claim 184 wherein the acid is selected from the group consisting of citric acid, acetic acid, nitric acid, sulfuric acid, hydrochloric acid, hydrofluoric acid and combinations thereof.

Claim 186. (Original) The method of claim 184 wherein the acid comprises hydrochloric acid.

Claim 187. (Original) The method of claim 150 wherein at least about 50 wt% of carbon in the carbon product is single-wall carbon nanotubes.

Claim 188. (Original) The method of claim 150 wherein at least about 80 wt% of carbon in the product is single-wall carbon nanotubes.

Claim 189. (Original) The method of claim 150 wherein at least about 90 wt% of carbon in the product is single-wall carbon nanotubes.

Claim 190. (Original) The method of claim 150 wherein at least about 95 wt% of carbon in the product is single-wall carbon nanotubes.

Claim 191. (Original) The method of claim 150 wherein the catalyst is flowed through a transport reactor entrained in the gaseous stream comprising the carbon-containing feedstock.

Claim 192. (Original) The method of claim 191 wherein at least one other gaseous stream comprising the carbon-containing feedstock is introduced to the reactor at more than one inlet.

Claim 193. (Original) The method of claim 192 wherein the at least one other gaseous stream comprises hydrogen.

Claim 194. (Original) The method of claim 191 wherein the reactor comprises more than one zone wherein each zone is capable of maintaining a different set of reaction conditions.

Claim 195. (Original) The method of claim 191 wherein the reactor further comprises a solid-gas separator selected from the group consisting of a wet scrubber, a cyclone, an electrostatic precipitator, filter, and combinations thereof.

Claim 196. (Original) The method of claim 191 wherein a dispersing aid is used in the transport reactor.

Claim 197. (Original) The method of claim 196 wherein the dispersing aid is a material selected from the group consisting of metal oxide particles, sand, quartz beads, ceramic particles, refractory material and combinations thereof.

Claim 198. (Original) The method of claim 150 wherein the catalyst is fluidized by the gaseous stream comprising the carbon-containing feedstock in a fluidized bed reactor.

Claim 199. (Original) The method of claim 198 wherein the fluidized bed reactor comprises more than one zone wherein each zone is capable of maintaining a different set of reaction conditions.

Claim 200. (Original) The method of claim 198 wherein a fluidizing aid is fluidized in the fluidized bed reactor.

Claim 201. (Original) The method of claim 200 wherein the catalyst and the carbon product are separated from the fluidizing aid by differential elutriation.

Claim 202. (Original) The method of claim 200 wherein the fluidizing aid exchanges heat with the catalyst.

Claim 203. (Original) The method of claim 200 wherein the fluidizing aid acts as a reactor wall scrubber.

Claim 204. (Original) The method of claim 200 wherein the fluidizing aid is a material selected from the group consisting of metal oxide particles, sand, quartz beads, ceramic particles, refractory material and combinations thereof.

Claim 205. (Original) The method of claim 150 wherein the contacting occurs in a moving bed reactor, wherein the reactor has a moving bed comprising the catalyst and essentially-inert particles.

Claim 206. (Original) The method of claim 205 wherein the moving bed reactor comprises more than one zone wherein each zone is capable of maintaining a different set of reaction conditions.

Claim 207. (Original) The method of claim 205 wherein the gaseous stream comprising the carbon-containing feedstock is introduced into the reactor at more than one inlet.

Claim 208. (Original) The method of claim 205 wherein the essentially-inert particles comprise a material selected from the group consisting of metal oxide particles, sand, quartz beads, ceramic particles, refractory material and combinations thereof.

Claim 209. (Original) The method of claim 205 wherein the essentially-inert particles are removed from the reactor, circulated and re-introduced to the reactor.

Claim 210. (Original) The method of claim 205 where the essentially-inert particles are regenerated after exiting the reactor.

Claim 211. (Original) The method of claim 205 wherein the essentially-inert particles are heated after exiting the reactor to produce essentially-inert heated particles.

Claim 212. (Original) The method of claim 205 wherein the essentially-inert heated particles are introduced into the reactor and exchange heat with the catalyst.

Claim 213. (Original) The method of claim 205 further comprising separating the catalyst and the carbon product from the essentially-inert particles.

Claim 214. (Original) The method of claim 213 wherein the separating is done by differential elutriation.

Claim 215. (Original) The method of claim 213 wherein the separating comprises a component selected from the group consisting of a cyclone, a classifier, a solid-gas separator, a

disengaging section, a wet scrubber, a cyclone, an electrostatic precipitator, a filter and combinations thereof.

Claim 216. (Original) The method of claim 205 wherein the moving bed reactor is a counter-current moving bed reactor, wherein the counter-current moving bed reactor has a moving bed comprising the essentially-inert particles that move in a direction counter-current to flows of the catalyst and the gaseous stream comprising the carbon-containing feedstock.

Claim 217. (Original) The method of claim 205 wherein the moving bed reactor is a concurrent-flow moving bed reactor wherein the essentially-inert particles and the catalyst flow in the same direction.

Claim 218. (Original) The method of claim 217 wherein the gaseous stream comprising the carbon-containing feedstock, the essentially inert particles and the catalyst flow in the same direction.

Claim 219. (Original) The method of claim 217 wherein the gaseous stream comprising the carbon-containing feedstock flows in an opposite direction to movement of the essentially-inert particles and the catalyst.

Claim 220. (Cancelled)

Claim 221. (Original) A method for producing single-wall carbon nanotubes, comprising:

- (a) providing a supported catalyst comprising at least one metal from the group consisting of Group VIB and Group VIIB;
- (b) feeding the supported catalyst, a carrier gas, a carbon-containing feedstock gas, and fluidizing aid particles to a fluidized bed reactor;
- (c) contacting the catalyst with the carbon-containing feedstock in the reactor at a sufficient temperature and for a contact time sufficient to make single-wall carbon nanotubes;
- (d) withdrawing an upper product stream from the reactor that comprises single-wall carbon nanotubes; and

- (e) separately withdrawing a lower product stream from the reactor that comprises fluidizing aid particles.

Claim 222. (Original) The method of claim 221 wherein the fluidizing aid particles from step (e) are recycled to the reactor.

Claim 223. (Original) The method of claim 222 wherein the fluidizing aid particles are heated before being recycled to the reactor.

Claim 224. (Original) A method for producing single-wall carbon nanotubes, comprising:

- (a) providing a supported catalyst comprising at least one metal from the group consisting of Group VIB and Group VIIB;
- (b) continuously feeding the supported catalyst, a carrier gas, a carbon-containing feedstock gas, and fluidizing aid particles to a reactor, wherein the fluidizing aid particles flow generally counter-current to the carrier gas and carbon-containing feedstock gas in the reactor;
- (c) contacting the catalyst with the carbon-containing feedstock in the reactor at a sufficient temperature and for a contact time sufficient to make single-wall carbon nanotubes;
- (d) withdrawing an upper product stream from the reactor that comprises single-wall carbon nanotubes; and
- (e) separately withdrawing a lower product stream from the reactor that comprises fluidizing aid particles.

Claim 225. (Original) The method of claim 224 wherein the fluidizing aid particles from step (e) are recycled to the reactor.

Claim 226. (Original) The method of claim 225 wherein the fluidizing aid particles are heated before being recycled to the reactor.

Claim 227. (Currently amended) A method for producing single-wall carbon nanotubes, comprising:

- (a) providing a supported catalyst comprising at least one metal from the group consisting of Group VIB and Group VIIIB;
- (b) continuously feeding the supported catalyst, a carrier gas, a carbon-containing feedstock gas, and fluidizing aid particles to a reactor, wherein the fluidizing aid particles generally flow in substantially the same direction as the carrier gas and carbon-containing feedstock gas in the reactor;
- (c) contacting the catalyst with the carbon-containing feedstock in the reactor at a sufficient temperature and for a contact time sufficient to make single-wall carbon nanotubes;
- (d) withdrawing ~~an~~ a product stream from the reactor that comprises single-wall carbon nanotubes, and fluidizing aid particles; and
- (e) separating the single-wall carbon nanotubes from the fluidizing aid particles.

Claim 228. (Original) The method of claim 227 wherein the fluidizing aid particles from step (e) are recycled to the reactor.

Claim 229. (Original) The method of claim 228 wherein the fluidizing aid particles are heated before being recycled to the reactor.

Claim 230. (Currently amended) A method for producing carbon nanotubes, comprising:

- (a) providing a supported catalyst comprising refractory particles and at least one or more catalytic metal selected from the group consisting of Group VIIIB, Group VIB and combinations thereof, wherein the catalyst is prepared by combusting a combination of Group VIIIB metal precursors, Group VIB metal precursors and refractory particle precursors; and
- (b) contacting the catalyst with a gaseous stream comprising a carbon-containing feedstock at a sufficient temperature and for a contact time sufficient to make a carbon product comprising carbon nanotubes.

Claim 231. (Original) The method of claim 230 wherein the carbon nanotubes are selected from the group consisting of multiwall carbon nanotubes, single-wall carbon nanotubes and a combination thereof.

Claim 232. (Original) The method of claim 230 wherein the catalytic metal comprises metals from both Group VIIIIB and Group VIB and wherein the Group VIIIIB metal and the Group VIB metal have a weight ratio in the range of about 10 to 1 to about 2 to 1.

Claim 233. (Original) The method of claim 230 wherein the catalytic metal comprises metals from both Group VIIIIB and Group VIB and wherein the Group VIIIIB metal and the Group VIB metal have a molar ratio in the range of about 20 to 1 to about 3 to 1.

Claim 234. (Original) The method of claim 230 wherein the catalytic metal is are present on the refractory particles at a loading in the range of about 0.5 wt% and about 10 wt% of the weight of the refractory particles.

Claim 235. (Cancelled)

Claim 236. (Currently amended) The method of claim ~~235~~ 230 wherein the Group VIIIIB metal precursor is selected from a Group VIIIIB-containing compound wherein the compound is selected the group consisting of a nitrate, a sulfite, a sulfate, a carbonate, an acetate, a citrate, a gluconate, a hexacyanoferrite, an oxalate, a tris(ethylenediamine) sulfate and combinations thereof.

Claim 237. (Currently amended) The method of claim ~~235~~ 230 wherein the Group VIB metal precursor is a Group VI-containing compound wherein the compound is an ammonium compound.

Claim 238. (Currently amended) The method of claim ~~235~~ 230 wherein the refractory particle precursor is a nitrate compound.

Claim 239. (Currently amended) The method of claim ~~235~~ 230 wherein the combusting includes a foaming agent.

Claim 240. (Original) The method of claim 239 wherein the foaming agent selected from the group consisting of citric acid, urea, glycine, hydrazine, sucrose, carbohydrazide, oxalyl dihydrazide, sugars, alcohols, and combinations thereof.

Claim 241. (Original) The method of claim 239 wherein the foaming agent comprises citric acid.

Claim 242. (Original) The method of claim 235 wherein the combusting is conducted by exposing the precursors to temperatures in the range of about 150°C and about 1200°C.

Claim 243. (Original) The method of claim 235 wherein the combusting is conducted by exposing the precursors to temperatures in the range of about 200°C and about 700°C.

Claim 244. (Original) The method of claim 235 wherein the combusting is conducted by exposing the precursors to temperatures in the range of about 250°C and about 650°C.

Claim 245. (Original) The method of claim 235 wherein the precursors are sprayed to form an aerosol prior to combustion.

Claim 246. (Original) The method of claim 235 wherein the combusting comprises contacting the precursors with a heated surface.

Claim 247. (Original) The method of claim 230 further comprising sulfiding the catalyst wherein the catalyst is exposed to a sulfur-containing compound.

Claim 248. (Original) The method of claim 247 wherein the sulfur-containing compound is selected from the group consisting of thiophene, hydrogen sulfide, a mercaptan and combinations thereof.

Claim 249. (Original) The method of claim 247 wherein the sulfur-containing compound comprises thiophene.

Claim 250. (Original) The method of claim 247 wherein the sulfiding is done prior to the contacting step.

Claim 251. (Original) The method of claim 247 wherein the sulfiding is done with the contacting step.

Claim 252. (Original) The method of claim 230 wherein the catalyst has a cross-sectional dimension of less than about 100 microns.

Claim 253. (Original) The method of claim 230 wherein the catalyst has a cross-sectional dimension of less than about 30 microns.

Claim 254. (Original) The method of claim 230 wherein the catalyst has a bulk density less than about 0.3 g/cm³.

Claim 255. (Original) The method of claim 230 wherein the catalyst has a bulk density less than about 0.1 g/cm³.

Claim 256. (Original) The method of claim 230 further comprising reducing the metal prior to the contacting step.

Claim 257. (Original) The method of claim 256 wherein the reducing is done with a reducing gas.

Claim 258. (Original) The method of claim 257 wherein the reducing gas comprises hydrogen.

Claim 259. (Original) The method of claim 230 wherein the metal is reduced during the contacting step.

Claim 260. (Original) The method of claim 230 wherein the temperature is in a range of about 500°C and about 1500°C.

Claim 261. (Original) The method of claim 230 wherein the temperature is in the range of about 650°C and about 950°C.

Claim 262. (Original) The method of claim 230 wherein the temperature is in the range of about 800°C and about 950°C.

Claim 263. (Original) The method of claim 230 wherein the carbon-containing feedstock comprises a compound selected from the group consisting of methane, hydrocarbons, carbon monoxide and combinations thereof.

Claim 264. (Original) The method of claim 230 wherein the gaseous stream comprising the carbon-containing feedstock comprises methane.

Claim 265. (Currently amended) The method of claim 230 further comprising mixing hydrogen with the ~~gaseous~~ gaseous stream comprising carbon-containing feedstock.

Claim 266. (Original) The method of claim 230 wherein the gaseous stream comprising the carbon-containing feedstock also comprises hydrogen.

Claim 267. (Original) The method of claim 230 wherein the gaseous stream comprising the carbon-containing feedstock comprises a mixture of methane and hydrogen.

Claim 268. (Original) The method of claim 230 further comprising mixing an oxidizing gas with gaseous stream comprising the carbon-containing feedstock.

Claim 269. (Original) The method of claim 268 wherein the oxidizing gas is selected from the group consisting of oxygen, water vapor, carbon dioxide and combinations thereof.

Claim 270. (Original) The method of claim 230 wherein the contact time is in a range of about 0.1 seconds and about 60 minutes.

Claim 271. (Original) The method of claim 230 wherein the contact time is in a range of about 0.1 seconds and about 30 minutes.

Claim 272. (Original) The method of claim 230 wherein the contact time is in a range of about 10 seconds and about 10 minutes.

Claim 273. (Original) The method of claim 230 wherein the single-wall carbon nanotubes have diameters controlled by the contact time in the contacting step.

Claim 274. (Original) The method of claim 230 wherein the single-wall carbon nanotubes have lengths controlled by the contact time in the contacting step.

Claim 275. (Original) The method of claim 230 wherein the contacting is done at a pressure between about 0.1 atmospheres and about 200 atmospheres.

Claim 276. (Original) The method of claim 230 further comprising removing the catalyst from the carbon product with an acid.

Claim 277. (Original) The method of claim 276 wherein the acid is selected from the group consisting of citric acid, acetic acid, nitric acid, sulfuric acid, hydrochloric acid, hydrofluoric acid and combinations thereof.

Claim 278. (Original) The method of claim 276 wherein the acid comprises hydrochloric acid.

Claim 279. (Original) The method of claim 230 wherein at least about 50 wt% of carbon in the carbon product is single-wall carbon nanotubes.

Claim 280. (Original) The method of claim 230 wherein at least about 80 wt% of carbon in the product is single-wall carbon nanotubes.

Claim 281. (Original) The method of claim 230 wherein at least about 90 wt% of carbon in the product is single-wall carbon nanotubes.

Claim 282. (Original) The method of claim 230 wherein at least about 95 wt% of carbon in the product is single-wall carbon nanotubes.

Claim 283. (Original) The method of claim 230 wherein the catalyst is flowed through a transport reactor entrained in the gaseous stream comprising the carbon-containing feedstock.

Claim 284. (Original) The method of claim 283 wherein at least one other gaseous stream comprising the carbon-containing feedstock is introduced to the reactor at more than one inlet.

Claim 285. (Original) The method of claim 284 wherein the at least one other gaseous stream comprises hydrogen.

Claim 286. (Original) The method of claim 283 wherein the reactor comprises more than one zone wherein each zone is capable of maintaining a different set of reaction conditions.

Claim 287. (Original) The method of claim 283 wherein the reactor further comprises a solid-gas separator selected from the group consisting of a wet scrubber, a cyclone, an electrostatic precipitator, filter, and combinations thereof.

Claim 288. (Original) The method of claim 283 wherein a dispersing aid is used in the transport reactor.

Claim 289. (Original) The method of claim 288 wherein the dispersing aid is a material selected from the group consisting of metal oxide particles, sand, quartz beads, ceramic particles, refractory material and combinations thereof.

Claim 290. (Original) The method of claim 230 wherein the catalyst is fluidized by the gaseous stream comprising the carbon-containing feedstock in a fluidized bed reactor.

Claim 291. (Original) The method of claim 290 wherein the fluidized bed reactor comprises more than one zone wherein each zone is capable of maintaining a different set of reaction conditions.

Claim 292. (Original) The method of claim 290 wherein a fluidizing aid is fluidized in the fluidized bed reactor.

Claim 293. (Original) The method of claim 292 wherein the catalyst and the carbon product are separated from the fluidizing aid by differential elutriation.

Claim 294. (Original) The method of claim 292 wherein the fluidizing aid exchanges heat with the catalyst.

Claim 295. (Original) The method of claim 292 wherein the fluidizing aid acts as a reactor wall scrubber.

Claim 296. (Original) The method of claim 292 wherein the fluidizing aid is a material selected from the group consisting of metal oxide particles, sand, quartz beads, ceramic particles, refractory material and combinations thereof.

Claim 297. (Original) The method of claim 230 wherein the contacting occurs in a moving bed reactor, wherein the reactor has a moving bed comprising the catalyst and essentially-inert particles.

Claim 298. (Original) The method of claim 297 wherein the moving bed reactor comprises more than one zone wherein each zone is capable of maintaining a different set of reaction conditions.

Claim 299. (Original) The method of claim 297 wherein the gaseous stream comprising the carbon-containing feedstock is introduced into the reactor at more than one inlet.

Claim 300. (Original) The method of claim 297 wherein the essentially-inert particles comprise a material selected from the group consisting of metal oxide particles, sand, quartz beads, ceramic particles, refractory material and combinations thereof.

Claim 301. (Original) The method of claim 297 wherein the essentially-inert particles are removed from the reactor, circulated and re-introduced to the reactor.

Claim 302. (Original) The method of claim 297 where the essentially-inert particles are regenerated after exiting the reactor.

Claim 303. (Original) The method of claim 297 wherein the essentially-inert particles are heated after exiting the reactor to produce essentially-inert heated particles.

Claim 304. (Original) The method of claim 297 wherein the essentially-inert heated particles are introduced into the reactor and exchange heat with the catalyst.

Claim 305. (Original) The method of claim 297 further comprising separating the catalyst and the carbon product from the essentially-inert particles.

Claim 306. (Original) The method of claim 305 wherein the separating is done by differential elutriation.

Claim 307. (Original) The method of claim 305 wherein the separating comprises a component selected from the group consisting of a cyclone, a classifier, a solid-gas separator, a disengaging section, a wet scrubber, a cyclone, an electrostatic precipitator, a filter and combinations thereof.

Claim 308. (Original) The method of claim 297 wherein the moving bed reactor is a counter-current moving bed reactor, wherein the counter-current moving bed reactor has a moving bed comprising the essentially-inert particles that move in a direction counter-current to flows of the catalyst and the gaseous stream comprising the carbon-containing feedstock.

Claim 309. (Original) The method of claim 297 wherein the moving bed reactor is a concurrent-flow moving bed reactor wherein the essentially-inert particles and the catalyst flow in the same direction.

Claim 310. (Original) The method of claim 309 wherein the gaseous stream comprising the carbon-containing feedstock, the essentially inert particles and the catalyst flow in the same direction.

Claim 311. (Original) The method of claim 309 wherein the gaseous stream comprising the carbon-containing feedstock flows in an opposite direction to movement of the essentially-inert particles and the catalyst.